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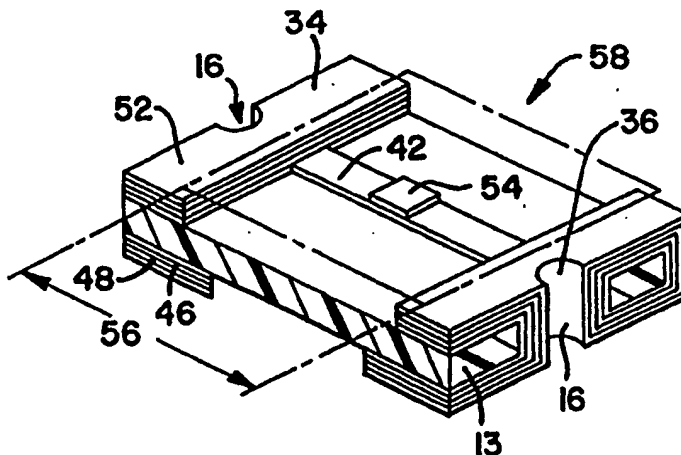
## Published

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(54) Title: IMPROVED METHOD AND APPARATUS FOR A SURFACE-MOUNTED FUSE DEVICE

## (57) Abstract

A thin film surface-mount fuse (58) having two material subassemblies. The first subassembly includes a fusible link (42), its supporting substrate (13) and terminal pads (34, 36). The second subassembly includes a protective layer (56) which overlies the fusible link (42) so as to provide protection from impacts and oxidation. The protective layer (56) is preferably made of a polymeric material. The most preferred polymeric material is a polyurethane gel or paste. In addition, the most preferred supporting substrate is an FR-4 epoxy or a polyimide.



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IMPROVED METHOD AND APPARATUS FOR A  
SURFACE-MOUNTED FUSE DEVICE

DESCRIPTION

Technical Field

The invention relates generally to a surface-mountable fuse for placement into and protection of the electrical circuit of a  
5 printed circuit board.

Related Application

The present application is a continuation-in-part application of U.S.  
10 Serial No. 08/247,584, filed May 27, 1994.

### Background Of The Invention

Printed circuit (PC) boards have found increasing application in electrical and electronic equipment of all kinds. The electrical circuits formed on these PC boards, like larger scale, conventional electrical circuits, need protection against electrical overloads. This protection is typically provided by subminiature fuses that are physically secured to the PC board.

One example of such a subminiature, surface-mounted fuse is disclosed in U.S. Patent No. 5,166,656 ('656 patent). The fusible link of this surface-mounted fuse is disclosed as being covered with a three layer composite which includes a passivation layer, an insulating cover, and an epoxy layer to bond the passivation layer to the insulating cover. See '656 patent, column 6, lines 4-7. Typically, the passivation layer is either chemically vapor-deposited silica or a thick layer of printed glass. See '656 patent, column 3, lines 39-41. The insulating cover may be a glass cover. See '656 patent, column 4, lines 43-46. The fuse from the '656 patent has three layers protecting its fusible link. In addition, the fuse from the '656 patent has relatively thick glass covering. There are several other features in the '656 patent fuse which are unnecessary in the present

invention. Thus, the present invention is designed to solve these and other problems.

#### Summary Of The Invention

5           The invention is a thin film, surface-mounted fuse which comprises two material subassemblies. The first subassembly comprises a fusible link, its supporting substrate and terminal pads. The second  
10 subassembly comprises a protective layer which overlies the fusible link so as to provide protection from impacts and oxidation.

          The protective layer is preferably made of a polymeric material. The most  
15 preferred polymeric material is a polyurethane gel or paste when the stencil printing step is used to apply the cover coat. However, polycarbonates will also work well when an injection molding step is used to apply the  
20 cover coat. In addition, the most preferred supporting substrate is an FR-4 epoxy or a polyimide.

          A second aspect of the invention is a thin film, surface-mounted fuse. This fuse  
25 comprises a fusible link made of a conductive metal. The first conductive metal is preferably, but not exclusively, selected from the group including copper, silver, nickel, titanium, aluminum or alloys of these  
30 conductive metals. A second conductive metal, different from the first conductive metal, is

deposited on the surface of this fusible link. One preferred metal for the surface-mounted fuse of this invention is copper. One preferred second conductive metal is tin-lead.  
5 Another preferred second conductive metal is tin.

The second conductive metal may be deposited onto the fusible link in the form of a rectangle, circle or in the form of any of  
10 several other configurations, depending on the configuration of the fuse link. The second conductive metal is preferably deposited along the central portion of the fusible link.

Photolithographic, mechanical and  
15 laser processing techniques may be employed to create very small, intricate and complex fusible link geometries. This capability, when combined with the extremely thin film coatings applied through electrochemical and  
20 physical vapor deposition (PVD) techniques, enables these subminiature fuses to control the fusible area of the element and protect circuits passing microampere- and ampere-range currents. This is unique, in that prior fuses  
25 providing protection at these high currents were made with filament wires. The manufacture of such filament wire fuses created certain difficulties in handling.

The location of the fusible link at  
30 the top of the substrate of the present fuse enables one to use laser processing methods as

a high precision secondary operation, in that way trimming the final resistance value of the fuse element.

5 **Brief Description Of The Drawings**

FIG. 1 is a perspective view of a copper-plated, FR-4 epoxy sheet used to make a subminiature surface-mounted fuse in accordance with the invention.

10 FIG. 2 is a view of a portion of the sheet of FIG. 1, and taken along lines 2-2 of FIG. 1.

FIG. 3 is a perspective view of the FR-4 epoxy sheet of FIG. 1, but stripped of  
15 its copper plating, and with a plurality of bores (partially shown), each having a diameter  $D$ , spaced apart by a length  $L$  and a width  $W$ , and routed into separate quadrants of that sheet.

20 FIG. 4 is an enlarged, perspective view of a cut-away portion of the bored sheet of FIG. 3, but with a copper plating layer having been reapplied.

FIG. 5 is a cut-away perspective  
25 view of the flat, upward-facing surfaces of the replated copper sheet, after the sheet was masked with a multi-squared panel of an ultraviolet (UV) light-opaque substance.

FIG. 6 is a perspective view of the  
30 reverse side of FIG. 5, rotated about one of the fuse rows 27, but after the removal of a

strip-like portion of copper plating from the replated sheet of FIG. 5.

FIG. 7 is a perspective view of the top-side of FIG. 6, rotated about one of the fuse rows 27, and showing linear regions 40 defined by dotted lines.

FIG. 8 is a perspective view of a single fuse row 27 from the sheet, cut away from the other fuse rows, and cut away at one edge of one of the fuses, after dipping the sheet into a copper plating bath and then a nickel plating bath, with the result that copper and nickel layers are deposited onto the base copper layer of the terminal pads, including the grooves of the pads.

FIG. 9 is a perspective view of the strip of FIG. 8, but prior to UV light curing, and showing a fuse-blowing portion 50 at the center of fusible link 42 that is masked with a UV light-opaque substance.

FIG. 10 shows the strip of FIG. 9, but after immersion into a tin-lead plating bath to create another layer over the copper and nickel layers, and after deposition of a tin-lead alloy onto the central portion of the fusible link.

FIG. 11 shows the strip of FIG. 10, but with an added polymeric gel or paste layer onto the top of the fuse row 27.

FIG. 12 shows the individual fuse in accordance with the invention as it is finally



made, and after a so-called dicing operation in which a diamond saw is used to cut the strips along parallel and perpendicular planes to form these individual surface-mountable  
5 fuses.

**Detailed Description Of  
The Preferred Embodiment**

While this invention is susceptible  
10 of embodiment in many different forms, there is shown in the drawings and will herein be described in detail a preferred embodiment of the invention. It is to be understood that the present disclosure is to be considered as  
15 an exemplification of the principles of the invention. This disclosure is not intended to limit the broad aspect of the invention to the illustrated embodiment or embodiments.

One preferred embodiment of the  
20 present invention is shown in FIG. 12. The thin film, surface-mounted fuse is a subminiature fuse used in a surface mount configuration on a PC board or on a thick film hybrid circuit. One of these fuses is  
25 typically known in the art as an "A" case fuse. The "A" case fuse standard industry size for these fuses is 125 mils. long by 60 mils. wide. The "A" case fuse is also designated as a 1206 fuse. In addition, the  
30 present invention includes even smaller sized fuses which are compatible with standard sized

surface mountable devices. In particular, the present invention can be used within all other standard sizes of such surface mountable device sizes, such as 1210, 0805, 0603 and  
5 0402 fuses, as well as non-standard sizes.

The invention generally comprises two material subassemblies. As will be seen, the first subassembly includes the fuse element or fusible link 42, its supporting  
10 substrate or core 13, and terminal pads 34 and 36 for connecting the fuse 58 to the PC board. The second subassembly is a protective layer 56 which overlies the fusible link 42 and a substantial portion of the top portion of the  
15 fuse so as to, at least, provide protection from impacts which may occur during automated assembly, and protection from oxidation during use.

The first subassembly contains and  
20 supports two metal electrodes or pads 34, 36, and the fusible element or link 42, both of which are bonded to the substrate as a single continuous film, as shown in FIGs. 5 and 6. The pads 34, 36 are located on the top, the  
25 bottom, and a the sides of the substrate or core 13, while the fusible link 42 is located at the top of the substrate 13. More specifically, the pads 34, 36 extend into the two grooves 16 (each groove 16 is one half of  
30 each bore 14) in each fuse created by the bores 14 and dicing operation during the

process of manufacture, as will be further described below.

As will be seen, in the preferred embodiment, pads are made up of several layers, including a base copper layer, a supplemental copper layer, a nickel layer and a tin-lead layer. The base copper layer of the pads and the thin film fusible link are simultaneously deposited by (1) electrochemical processes, such as the plating described in the preferred embodiment below; or (2) by PVD. Such simultaneous deposition ensures a good conductive path between the fusible link 42 and the terminal pads 34, 36. This type of deposition also facilitates manufacture, and permits very precise control of the thickness of the fusible link 42.

After initial placement of the fusible link 42 and the base copper onto the substrate 13, additional layers of a conductive metal are placed onto the terminal pads 34, 36. These additional layers could be defined and placed onto these pads by photolithography and deposition techniques, respectively.

This fuse may be made by the following process. Shown in FIGS. 1 and 2 is a solid sheet 10 of an FR-4 epoxy with copper plating 12. The copper plating 12 and the FR-4 epoxy core 13 of this solid sheet 10 may best be seen in FIG. 2. This copper-plated

FR-4 epoxy sheet 10 is available from Allied Signal Laminate Systems, Hoosick Falls, New York, as Part No. 0200BED130C1/C1GFN0200 C1/C1A2C. Although FR-4 epoxy is a preferred material, other suitable materials include any material that is compatible with, i.e., of a chemically, physically and structurally similar nature to, the materials from which PC boards are made. Thus, another suitable material for this solid sheet 10 is polyimide. FR-4 epoxy and polyimide are among the class of materials having physical properties that are nearly identical with the standard substrate material used in the PC board industry. As a result, the fuse of the invention and the PC board to which that fuse is secured have extremely well-matched thermal and mechanical properties. The substrate of the fuse of the present invention also provides desired arc-tracking characteristics, and simultaneously exhibits sufficient mechanical flexibility to remain intact when exposed to the rapid release of energy associated with arcing.

In the next step of the process of manufacturing the fuses of the present invention, the copper plating 12 is etched away from the solid sheet 10 by a conventional etching process. In this conventional etching process, the copper is etched away from the substrate by a ferric chloride solution.

Although it will be understood that after completion of this step, all of the copper layer 12 of FIG. 2 is etched away from FR-4 epoxy core 13 of this solid sheet 10, the remaining epoxy core 13 of this FR-4 epoxy sheet 10 is different from a "clean" sheet of FR-4 epoxy that had not initially been treated with a copper layer. In particular, a chemically etched surface treatment remains on the surface of the epoxy core 13 after the copper layer 12 has been removed by etching. This treated surface of the epoxy core 13 is more receptive to subsequent operations that are necessary in the manufacture of the present surface-mounted subminiature fuse.

The FR-4 epoxy sheet 10 having this treated, copper-free surface is then drilled or punched to create holes or bores 14 along four quadrants 10a, 10b, 10c, 10d of the sheet 10, as may be seen in FIG. 3. Broken lines visually separate these four quadrants 10a, 10b, 10c, 10d in FIG. 3. It should be further noted that in FIG. 3, the bores 14 are lined up into rows 27 and columns 29. Although only four rows 27 of bores 14 are shown in FIG. 3 in one quadrant 10a for convenience, the rows 27 of holes 14 are actually disposed over almost the entire sheet 10 in all four quadrants 10a, 10b, 10c, 10d, as is designated by the three dots 11. For the "603" standard sizing of surface mounted devices mentioned

above, the length L between the center of the bores 14 is approximately 70 mils, and the width W between the center of the bores 14 is approximately 38 mils. For the "402" standard sizing of surface mounted devices mentioned above, the length L between the center of the bores 14 is approximately 50 mils, and the width W between the center of the bores 14 is approximately 30 mils. Again, smaller and larger standard and non-standard sizings are possible for the present invention. The diameter D (FIG. 4) for each bore 14 for the "603" sizing is approximately 18 mils.

When the drilling or punching of the bores 14 has been completed, the etched and bored sheet 10 shown in FIG. 3 is again plated with copper. This reapplication of copper occurs through the immersion of the etched and bored sheet of FIG. 3 into an electroless copper plating bath. This method of copper plating is well-known in the art.

This copper plating step results in the placement of a copper layer having a uniform thickness along each of the exposed surfaces of the sheet 10. For example, as may be seen in FIG. 4, the copper plating 18 resulting from this step covers both (1) the flat, upper surfaces 22 of the sheet 10; and (2) the vertical regions of the grooves 16 and/or the vertical regions of the bores 14. These vertical portion of the grooves 16

and/or bores 14 must be copper-plated because they will ultimately form a portion of the terminal pads 34, 36 of the final fuse as will be further described below.

5           The uniform thickness of the copper plating will depend upon the ultimate needs of the user. Particularly, as may be seen in FIG. 4, for a fuse intended to open at 1/16  
10           ampere, the copper plating 18 has a thickness of 2,500 Angstroms. For a fuse intended to open at 5 amperes, the copper plating 18 has a thickness of approximately 75,000 Angstroms for a particular width of the fusable link.

          After plating has been completed, to  
15           arrive at the copper-plated structure of FIG. 4, the entire exposed surface of this structure is covered with a so-called photoresist polymer.

          An otherwise clear mask is placed  
20           over the replated copper sheet 20 from FIG. 4 after it has been covered with the photoresist. Square panels are a part of, and are evenly spaced across, this clear mask according to the sizing of the fuse being  
25           manufactured. These square panels are made of an UV light-opaque substance, and are generally shown as the rectangle 30 shown in FIG. 5. Essentially, by placing this mask having these panels onto the replated copper  
30           sheet 20, several portions of the flat, upward-facing surfaces 22 of the replated

copper sheet 20 from FIG 4. are effectively shielded from the effects of UV light.

It will be understood from the following discussion that these square panels will essentially define the shapes and sizes of the so-called fusible link 42 and the upper terminal areas 60 of the terminal pads 34, 36 on the upper portion 22 of the fuse. The fusible link 42 is in electrical communication with the upper terminal areas 60. It will be appreciated that the width, length and shape of both the fusible link 42 and these upper terminal areas 60 may be altered by changing the size and shape of these UV light-opaque panels.

Additionally, the backside of the sheet is covered with a photoresist material and an otherwise clear mask is placed over the replated copper sheet 20 after it has been covered with the photoresist. A rectangular panel is a part of this clear mask. The rectangular panels are made of a UV light-opaque substance, and are of a size corresponding to the size of the panel 28 shown in FIG. 6. Essentially, by placing this mask having these panels onto the replated copper sheet 20, several strips of the flat, downward-facing surfaces 28 of the replated copper sheet 20 are effectively shielded from the effects of the UV light. The rectangular panels will essentially define the shapes and



sizes of the lower terminal areas 62 of the terminal pads 34, 36, and the lower middle portions 28 of sheet 20, as shown in FIG. 6.

5 The copper plating from a portion of the underside of a sheet 20 is defined by a photoresist mask. Particularly, the copper plating from the lower, middle portions 28 of the underside of the sheet 20 is removed. The lower, middle portions 28 of the underside of the sheet 20 is that part of the strip along a line immediately beneath the areas 30 of clear epoxy, and the fuse links 42. A perspective view of this section of this replated sheet 20 is shown in FIG. 6.

15 The entire replated, photoresist-covered sheet 20, i.e., the top, bottom and sides of that sheet, is then subjected to UV light. The replated sheet 20 is subjected to the UV light for a time sufficient to ensure curing of all of the photoresist that is not covered by the square panels and rectangular strips of the masks. Thereafter, the masks containing these square panels and rectangular strips are removed from the replated sheet 20.

20 The photoresist that was formerly below these square panels remains uncured. This uncured photoresist may be washed from the replated sheet 20 using a solvent.

25 The cured photoresist on the remainder of the replated sheet 20 provides protection against the next step in the

30

process. Particularly, the cured photoresist prevents the removal of copper beneath those areas of cured photoresist. The regions formerly below the square panels have no cured photoresist and no such protection. Thus, the copper from those regions can be removed by etching. This etching is performed with a ferric chloride solution through well known etching concepts.

After the copper has been removed, as may be seen in FIGS. 5 and 6, the regions formerly below the square panels and the rectangular strips of the mask are not covered at all. Rather, those regions now comprise areas 28 and 30 of clear epoxy.

The replated sheet 20 is then placed in a chemical bath to remove all of the remaining cured photoresist from the previously cured areas of that sheet 20.

After completion of several of the operations described in this specification, this sheet 20 will ultimately be cut into a plurality of pieces, and each of these pieces becomes a fuse in accordance with the invention, as will be further described below. However, for the purpose of brevity, only a cut-away portion of the overall sheet including three rows 27 and four columns 29 is shown in FIGS. 5 through 7. As may also be seen from FIG. 5 through 7, the bores 14 and grooves of the sheet 20 still include copper

plating. These bores 14 and grooves 16 form portions of the pads 34, 36. These pads 34, 36 will ultimately serve as the means for securing the entire, finished fuse to the PC  
5 board.

FIG. 7 is a perspective view of the opposite side of the sheet 20 from FIG. 6. Directly opposite and coinciding with the lower, middle portions 28 of the sheet 20 are  
10 linear regions 40 on the top-side 38 of the sheet 20. These linear regions 40 are defined by the dotted lines of FIG. 7.

FIG. 7 is to be referred to in connection with the next step in the  
15 manufacture of the invention. In this next step, a photoresist polymer is placed along each of the linear regions 40 of the top side 38 of the sheet 20. Through the covering of these linear regions 40, photoresist polymer  
20 is also placed along the relatively thin portions which will comprise the fusible links 42. These fusible links 42 are made of a conductive metal, here copper. The photoresist polymer is then treated with UV  
25 light, resulting in a curing of the polymer onto linear region 40 and its fusible links 42.

As a result of the curing of this photoresist onto the linear region 40 and its  
30 fusible links 42, metal will not adhere to this linear region 40 when the sheet 20 is

dipped into an electrolytic bath containing a metal for plating purposes.

In addition, as explained above, the middle portion 28 of the underside of the sheet 20 will also not be subject to plating when the sheet 20 is dipped into the electrolytic plating bath. Copper metal previously covering this metal portion had been removed, revealing the bare epoxy that forms the base of the sheet 20. Metal will not adhere to or plate onto this bare epoxy using an electrolytic plating process.

The entire sheet 20 is dipped into an electrolytic copper plating bath and then an electrolytic nickel plating bath. As a result, as may be seen in FIG. 8, a copper layer 46 and a nickel layer 48 are deposited on the base copper layer 44. After deposition of these copper 46 and nickel layers 48, the cured photoresist polymer on the linear region 40, including the photoresist polymer on the fusible links 42, is removed from that region 40.

Photoresist polymer is then immediately reapplied along the entire linear region 40. As may be seen in FIG. 9, however, a portion 50 at the center of the fusible link 42 is masked with a UV light-opaque substance. The entire linear region 40 is then subjected to UV light, with the result that curing of the photoresist polymer occurs on all of that

region, except for the masked central portion 50 of the fusible link 42. The mask is removed from the central portion 50 of the fusible link, and the sheet 20 is rinsed. As  
5 a result of this rinsing, the uncured photoresist above the central portion 50 of the fusible link 42 is removed from the fusible link 42. The cured photoresist along the remainder of the linear region 40,  
10 however, remains.

Plating of metal will not occur on the portion of the sheet 20 covered by the cured photoresist. Because of the absence of the photoresist from the central portion 50 of  
15 the fusible link 42, however, metal may be plated onto this central portion 50.

When the strip shown in FIG. 9 is dipped into an electrolytic tin-lead plating bath, a tin-lead layer 52 (FIG. 10) is  
20 overlain over the copper 46 and nickel layers 48. A tin-lead spot 54 is also deposited onto the surface of the fusible link 42, i.e., essentially placed by an electrolytic plating process onto the central portion 50 of the  
25 fusible link 42. This electrolytic plating process is essentially a thin film deposition process. It will be understood, however, that this tin-lead may also be added to the surface of the fusible link 42 by a photolithographic  
30 process or by means of a physical vapor deposition process, such as sputtering or

evaporation in a high vacuum deposition chamber.

This spot 54 is comprised of a second conductive metal, i.e., tin-lead or tin, that is dissimilar to the copper metal of the fusible link 42. This second conductive metal in the form of the tin-lead spot 54 is deposited onto the fusible link 42 in the form of a rectangle.

The tin-lead spot 54 on the fusible link 42 provides that link 42 with certain advantages. First, the tin-lead spot 54 melts upon current overload conditions, creating a fusible link 42 that becomes a tin-lead-copper alloy. This tin-lead-copper alloy results in a fusible link 42 having a lower melting temperature than the copper alone. The lower melting temperature reduces the operating temperature of the fuse device of the invention, and this results in improved performance of the device.

Although a tin-lead alloy is deposited on the copper fusible link 42 in this example, it will be understood by those skilled in the art that other conductive metals may be placed on the fusible link 42 to lower its melting temperature, and that the fusible link 42 itself may be made of conductive metals other than copper. In addition, the tin-lead alloy or other metal deposited on the fusible link 42 need not be

of a rectangular shape, but can take on any number of additional configurations.

The second conductive metal may be placed in a notched section of the link, or in  
5 holes or voids in that link. Parallel fuse links are also possible. As a result of this flexibility, specific electrical characteristics can be engineered into the fuse to meet varying needs of the ultimate  
10 user.

As indicated above, one of the possible fusible link configurations is a serpentine configuration. By using a serpentine configuration, the effective length  
15 of the fusible link may be increased, even though the distance between the terminals at the opposite ends of that link remain the same. In this way, a serpentine configuration provides for a longer fusible link without  
20 increasing the dimensions of the fuse itself.

The next step in the manufacture of the device of the invention is the placement, across a significant portion of the top of the sheet 20 between the terminal pads 34, 36, of  
25 a protective layer 56 (FIG. 11). This protective layer 56 is the second subassembly of the present fuse, and forms a relatively tight seal over the portion of the top of the sheet where the fusible links 42 exist. In  
30 this way, the protective layer 56 inhibits corrosion of the fusible links 42 during their

useful lives. The protective layer 56 also provides protection from oxidation and impacts during attachment to the PC board. This protective layer also serves as a means of  
5 providing for a surface for pick and place operations which use a vacuum pick-up tool.

This protective layer 56 helps to control the melting, ionization and arcing which occur in the fusible link 42 during  
10 current overload conditions. The protective layer 56 or cover coat material provides desired arc-quenching characteristics, especially important upon interruption of the fusible link 42.

15 The protective layer 56 may be comprised of a polymer, preferably a polyurethane gel or paste when a stencil print operation is used to apply the cover coat. A preferred polyurethane is made by Dymax  
20 Corporation. Other similar gels, pastes, or adhesives are suitable for the invention. In addition to polymers, the protective layer 56 may also be comprised of plastics, conformal coatings and epoxies.

25 This protective layer 56 is applied to the strips 26 using a stencil printing process which includes the use of a common stencil printing machine. In the past, an injection of the material into a die mold was  
30 performed while the sheet 20 was clamped between two dies. However, stencil printing



is a much faster process. Specifically, it has been found that the use of a stencil printing process while using a stencil printing machine, at least, doubles production output of the number of fuses from a previous die mold operation. The stencil printing machine is made by Affiliated Manufacturers, Inc. of Northbranch, New Jersey, Model No. CP-885.

10 In the stencil printing process, the material is applied to the sheet 20 in strips simultaneously, instead of two strips at a time in the die mold/injection filling process. As will be further explained below, 15 the material is cured much faster than the injection fill process because in the stencil printing process, the cover coat material is completely exposed to the UV radiation from the lamps as opposed to the injection filling 20 process where you have a filter that you have to transmit the energy from the lamp to the coating itself because the mold itself acts as a filter. Furthermore, the stencil printing process produces a more uniform cover coat 25 than the injection filling process, in terms of the height, the width of the cover coat. Because of that uniformity, the fuses can be tested and packaged automatically. With the injection filling process it was sometimes 30 difficult to precisely align the fuses in testing and packaging equipment due to some

non-uniform heights and widths of the cover coat.

The stencil printing machine comprises a slidable plate 70, a base 72, a squeegee arm 74, a squeegee 76, and an overlay 78. The overlay 78 is mounted on the base 72 and the squeegee 76 is movably mounted on the squeegee arm 74 above the base 72 and overlay 78. The plate 70 is slidable underneath the base 72 and overlay 78. The overlay 78 has parallel openings 80 which correspond to the width of the cover coat 56.

The stencil printing process begins by attaching an adhesive tape under the fuse sheet 20. The fuse sheet 20, with the adhesive tape, is placed on the plate 70 with the adhesive tape between the plate 70 and the fuse sheet 20. The cover coat material is then applied with a syringe at one end of the overlay 78. The plate 70 then slides underneath the overlay 78 and lodges the sheet 20 underneath the overlay 78 in correct alignment with the parallel openings 80. The squeegee 76 then lowers to contact the overlay 78 beyond the material on the top of the overlay 78. The squeegee 76 then moves across the overlay 78 where the openings 80 exist, thereby forcing the cover coat material through the openings 80 and onto the sheet. Thus, the cover coat now covers the fuse link area 40 (FIGS. 8 & 9). The squeegee 76 is

then raised, the sheet 20 is unlodged from the overlay 78, and the sheet 20 is placed in a UV light chamber so that the material can solidify and form the protective layer 56 (FIGS. 11 & 12). The openings 80 in the overlay 78 are wide enough so that the protective layer partially overlaps the pads 34, 36, as shown in FIGS. 11 & 12. In addition, the material used for the cover coat should have a viscosity in the gel or paste range so that after the material is spread onto the sheet 20, it will flow in a manner which creates a generally flat top surface 49, but not flow into the holes 14 or groves 16.

Although a colorless, clear cover coat is aesthetically pleasing, alternative types of cover coats may be used. For example, colored, clear materials may be used. These colored materials may be simply manufactured by the addition of a dye to a clear polyurethane gel or paste. Color coding may be accomplished through the use of these colored gels and pastes. In other words, different colors of gels can correspond to different amperages, providing the user with a ready means of determining the amperage of any given fuse. The transparency of both of these coatings permit the user to visually inspect the fusible link 42 prior to installation, and during use, in the electronic device in which the fuse is used.

The use of this protective layer 56 has significant advantages over the prior art, including the prior art, so-called, "capping" method. Due to the placement of the  
5 protective layer 56 over the entire top of a fuse body, the location of the protective layer relative to the location of the fusible link 42 is not critical.

The sheet 20 is then ready for a so-called dicing operation, which separates the  
10 rows and columns 27, 29 from one another, and into individual fuses. In this dicing operation, a diamond saw or the like is used to cut the sheet 20 along parallel planes 57  
15 (FIG. 11), and again perpendicular to planes 57, through the center of the holes 14, into individual thin film surface-mounted fuses 58 (FIG. 12). One of the directions of cuts bisect the terminal areas through the center  
20 of the holes 14, thereby exposing and creating the grooves 16 of the terminal pads 34, 36. These grooves 16 appear on either side of the fusible link 42.

This cutting operation completes the  
25 manufacture of the thin film surface-mounted fuse 58 (FIG. 12) of the present invention.

Fuses in accordance with this invention are rated at voltages and amperages greater than the ratings of prior art devices.  
30 Tests have indicated that fuses which fall under the "603" standard sizing would have a

fuse voltage rating of 32 volts AC, and a fuse  
amperage rating of between 1/16 ampere and 2  
amperes. Even though the fuses in accordance  
with this invention can protect circuits over  
5 a broad range of amperage ratings, the actual  
physical size of these fuses remains constant.

In summary, the fuse of the present  
invention exhibits improved control of fusing  
characteristics by regulating voltage drops  
10 across the fusible link 42. Consistent  
clearing times are ensured by (1) the ability  
to control, through deposition and  
photolithography processes, the dimensions and  
shapes of the fusible link 42 and terminal  
15 pads 34, 36; and (2) proper selection of the  
materials of the fusible link 42. Restriking  
tendencies are minimized by selection of an  
optimized material for the substrate 13 and  
protective layer 56.

20 While the specific embodiments have  
been illustrated and described, numerous  
modifications come to mind without  
significantly departing from the spirit of the  
invention, and the scope of protection is only  
25 limited by the scope of the accompanying  
Claims.

CLAIMS

What is claimed is:

1. A thin film surface-mount fuse,  
said fuse comprising two material  
subassemblies:
  - a. the first subassembly comprising  
5 a fusible link, a supporting substrate and  
terminal pads including a plurality of  
conductive terminal pad layers, the supporting  
substrate having an upper surface, lower  
surface and opposing side surfaces, a first of  
10 the plurality of conductive terminal pad  
layers and the fusible link formed as a  
single-continuous layer and extending across  
the upper surface of the supporting substrate,  
the first of the conductive terminal pad  
15 layers further extending over at least a part  
of the opposing side surfaces and terminating  
on the lower surface of the substrate; and,  
b. the second subassembly  
comprising a single protective layer which  
20 overlies the fusible link so as to provide  
protection from impacts and oxidation.
2. The surface-mount fuse of Claim  
1, wherein said protective layer is made of a  
polymeric material.
3. The surface-mount fuse of Claim  
1, wherein said protective layer is made of a  
polyurethane material.

4. The surface-mount fuse of Claim 1, wherein said supporting substrate is made of an FR-4 epoxy or a polyimide.

5. The surface-mount fuse of Claim 1, wherein said polymeric material is clear and colorless.

6. The surface-mount fuse of Claim 2, wherein said polymeric material is clear and colored.

7. A method for the manufacture of a thin film surface-mount fuse, comprising simultaneously depositing, upon the top of the substrate, a fusible link and a terminal pad  
5 at opposite ends of said fusible link.

8. The method as set forth in Claim 7, further comprising depositing, upon a portion of the sides and upon the bottom of a substrate, terminal pads electrically  
5 communicative with fuse link, said pads for connecting said surface-mount fuse with a printed circuit board.

9. The method as set forth in Claim 7, wherein said fusible link and wide terminals are deposited by vapor deposition.

10. The method as set forth in Claim 7, wherein said fusible link and wide terminals are electrochemically deposited.

11. A method of protecting a thin film surface-mount fuse having a fusible link and terminal pads, the terminal pads having a plurality of conductive terminal pad layers and the substrate having a top, a bottom and opposing side surfaces, wherein a first of the plurality of conductive terminal pad layers and the fusible link form a single continuous film which extends across the top surface of the substrate, the first of the conductive terminal pad layers further extending over at least a part of the opposing side surfaces and terminating on the lower surface of the substrate, said method comprising placing a single protective layer over the entire top surface of the substrate.



12. A thin film surface mount fuse comprising:

- a. a substrate;
- b. a fusible link and a first  
5 terminal pad layer formed as a single continuous layer disposed on the substrate, wherein the fusible link and the first terminal pad layer are made of a metal selected from a group consisting of copper,  
10 silver, nickel, titanium, aluminum and alloys thereof;
- c. a second terminal pad layer disposed on the first terminal pad layer, wherein the second terminal pad is made of the  
15 same metal as the first layer;
- d. a third terminal pad layer disposed on the second terminal pad layer, wherein the third terminal pad layer is made of nickel; and,
- 20 e. a fourth terminal pad layer disposed on the third terminal pad layer, wherein the fourth terminal pad layer is made of tin-lead or tin.

13. The surface mount fuse of Claim 12, wherein the fusible link has a central portion with a tin-lead spot being disposed on the central portion.

14. The surface mount fuse of Claim 12, wherein a protective coating is applied over the fusible link.

15. The surface mount fuse of Claim 14, wherein the protective coating is also applied over a portion of the fourth terminal pad layer.

16. A thin film surface-mount fuse, said fuse comprising:

- a. a substrate;
- b. a fusible link made of a first  
5 conductive metal deposited on the substrate;
- c. a second conductive metal,  
other than the first conductive metal,  
deposited on the surface of the fusible link;
- d. terminal pads electrically  
10 connected to the fusible link, the terminal  
pads having a plurality of conductive layers,  
wherein a first of the plurality of conductive  
layers and the fusible link are deposited  
simultaneously to form a single continuous  
15 film.

17. The device of Claim 16, wherein  
a second of the plurality of conductive layers  
is deposited on the first of the plurality of  
conductive layers and consists of the same  
5 metal as the first conductive metal.

18. The device of Claim 17, wherein a third of the plurality of conductive layers is deposited on the second of the plurality of conductive layers and consists of nickel.

19. The device of Claim 18, wherein a fourth of the plurality of conductive layers is deposited on the third of the plurality of conductive layers and consists of tin-lead.

20. The surface-mount fuse of Claim 16, wherein the first conductive metal is selected from the group including copper, silver, nickel, titanium, aluminum or alloys thereof.

21. The surface-mount fuse of Claim 16, wherein the second conductive metal is a tin-lead alloy.

22. The surface-mount fuse of Claim 21, wherein the second conductive metal is deposited onto the fusible link in the form of a rectangle.

23. The surface-mount fuse of Claim 22, wherein the fusible link has a central portion and the rectangle is deposited along the central portion of said fusible link.

FIG. 1

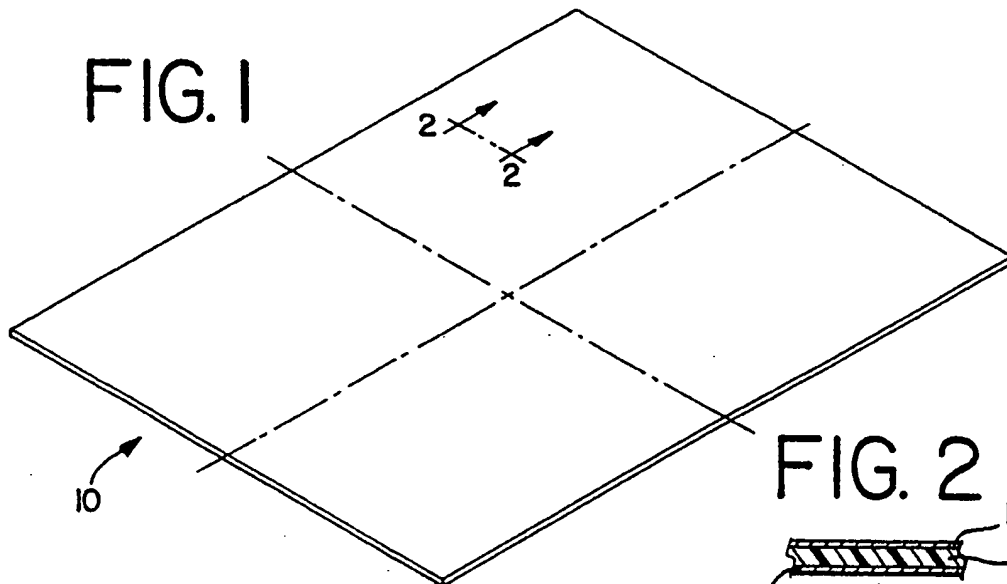


FIG. 2

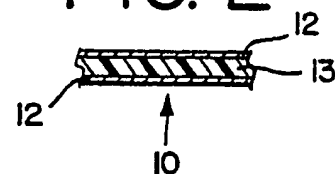


FIG. 3

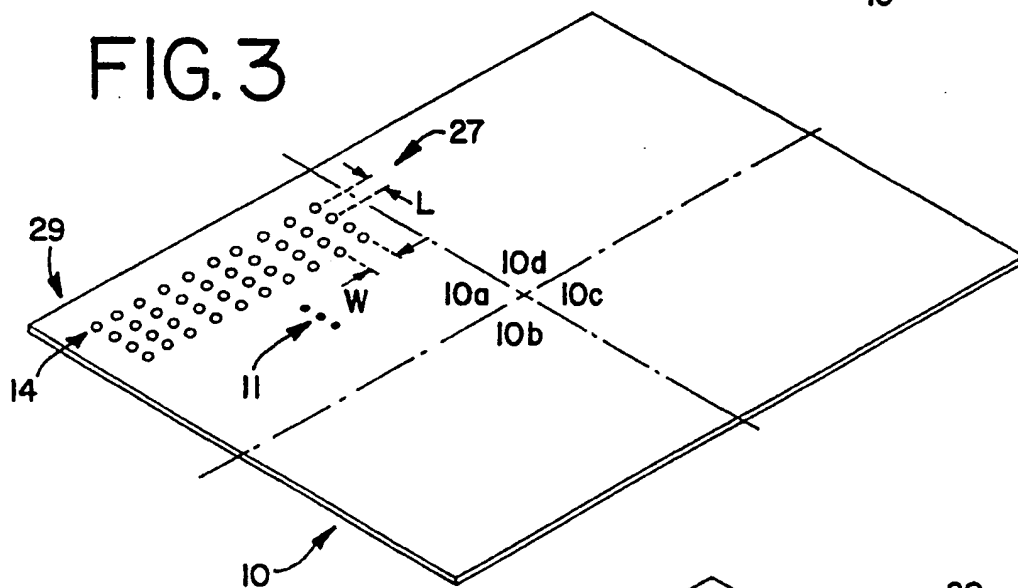
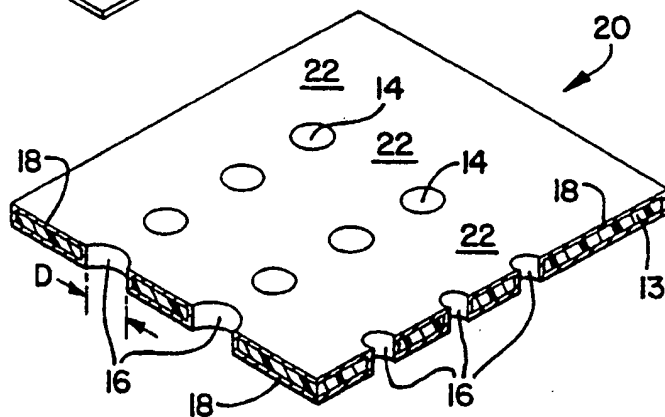


FIG. 4



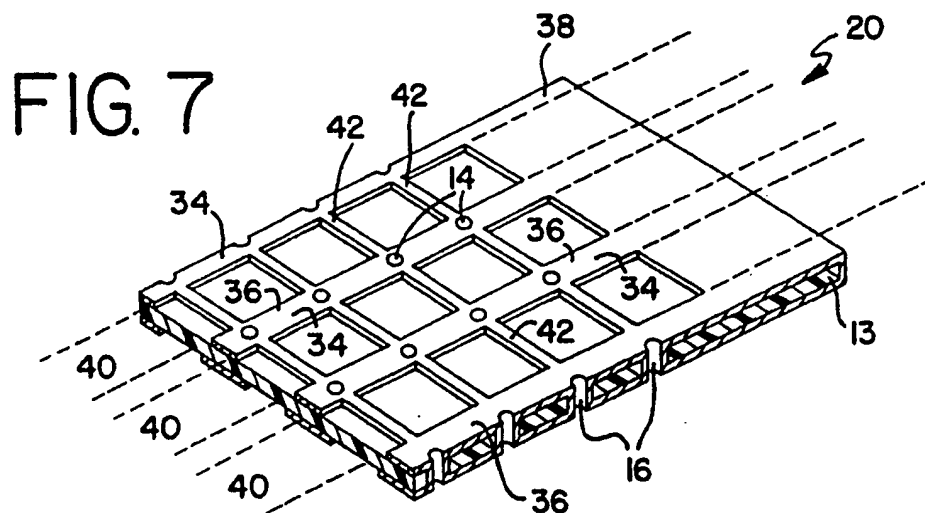
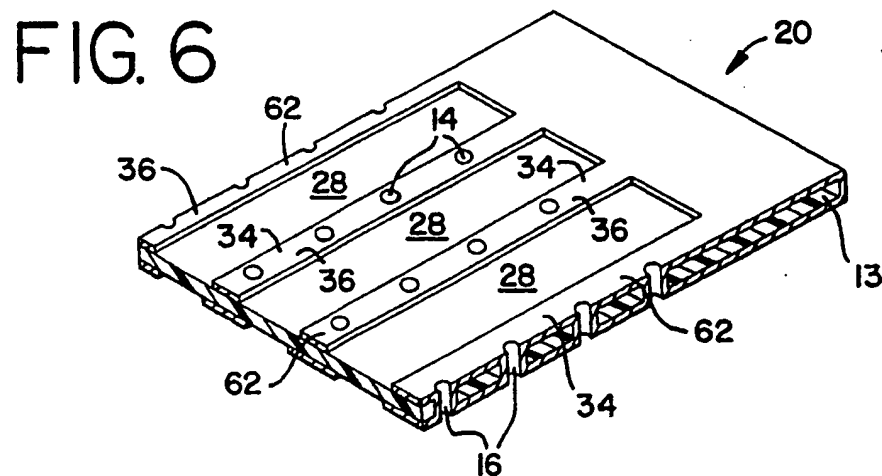
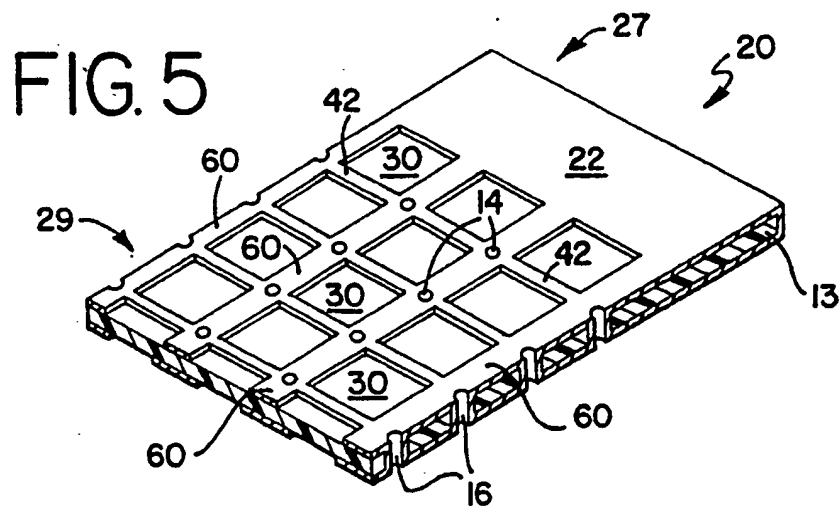


FIG. 8

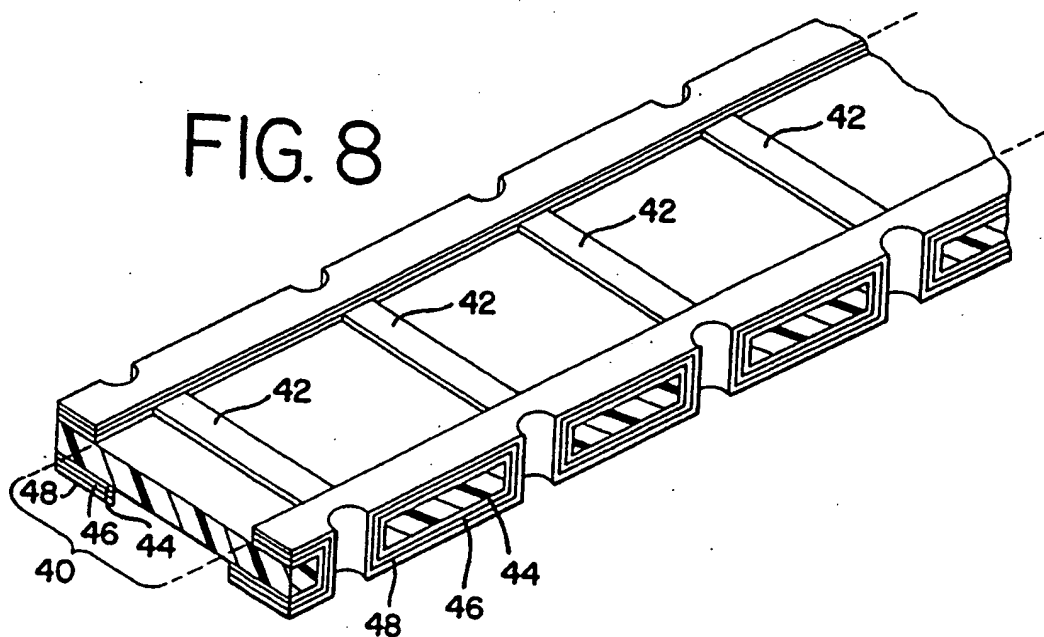


FIG. 9

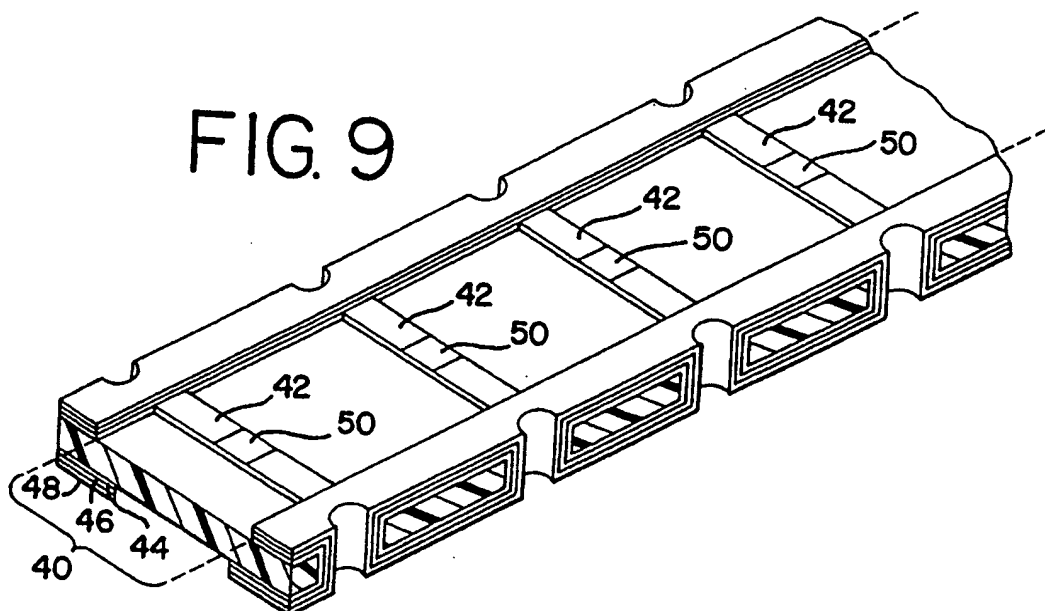


FIG. 10

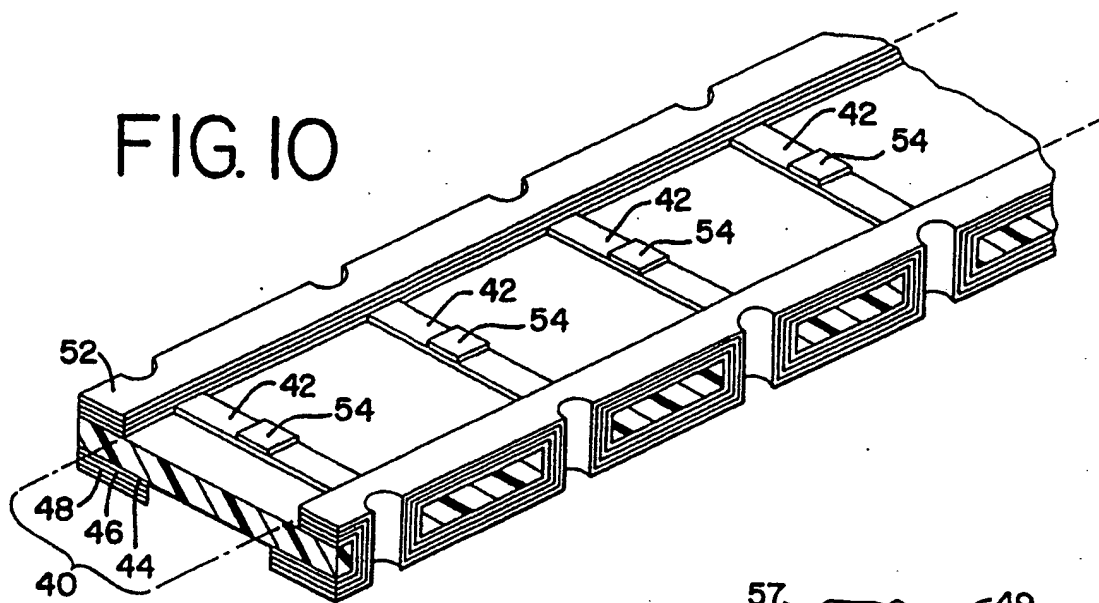


FIG. 11

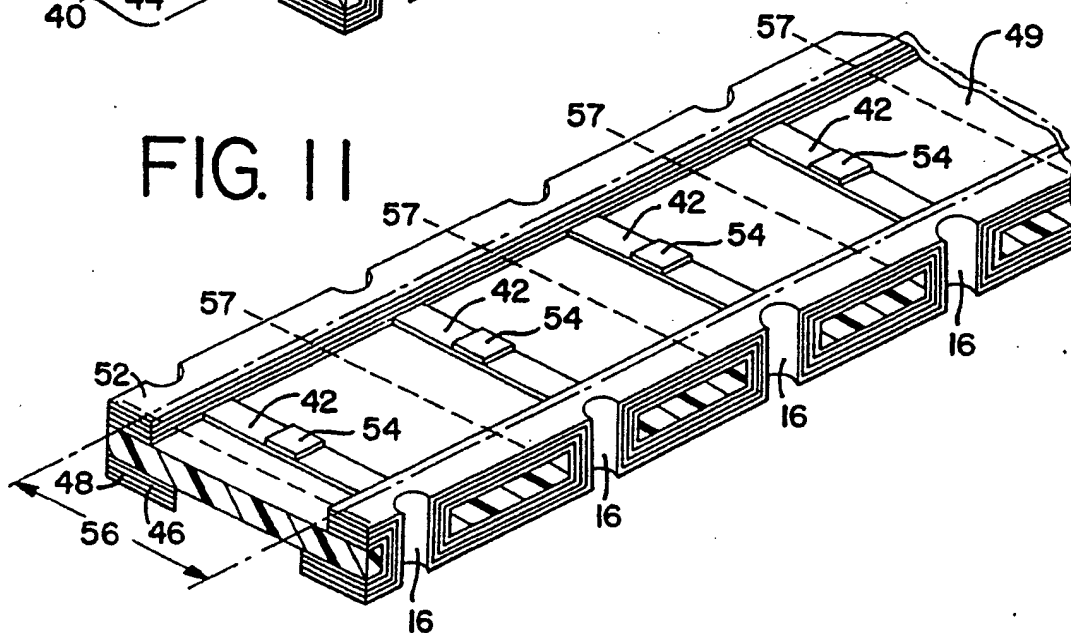


FIG. 12

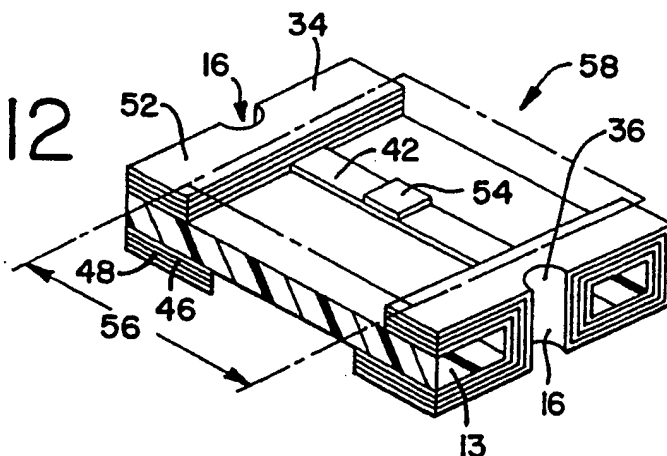
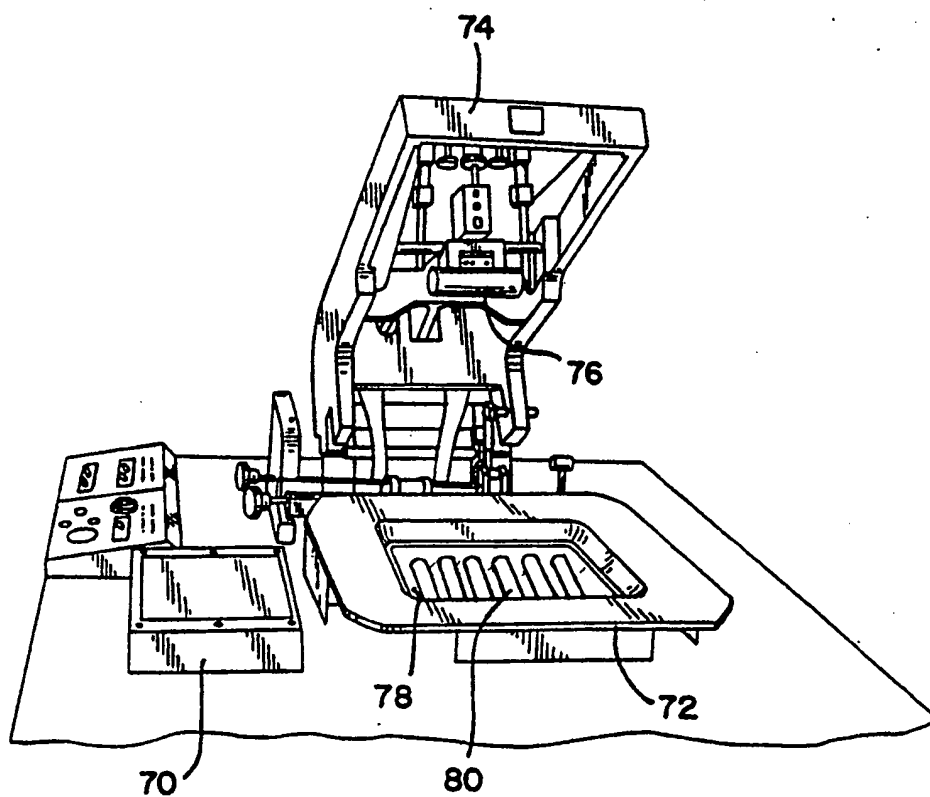


FIG. 13





## INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 96/09147

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01H85/046 H01H69/02

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP,A,0 270 954 (OMRON TATEISI ELECTRONICS CO) 15 June 1988 see the whole document	1-6, 11
Y	--- PATENT ABSTRACTS OF JAPAN vol. 017, no. 566 (E-1446), 13 October 1993 & JP,A,05 166454 (HITACHI CHEM CO LTD), 2 July 1993, see abstract	1-6, 11
Y	--- EP,A,0 581 428 (SUMITOMO WIRING SYSTEMS) 2 February 1994 see the whole document --- -/--	1-6, 11

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
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- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

4 November 1996

Date of mailing of the international search report

13. 11. 96

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## INTERNATIONAL SEARCH REPORT

International Application No  
PCI/US 96/09147

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 035 (E-1310), 22 January 1993 & JP,A,04 255627 (HITACHI CHEM CO LTD), 10 September 1992, see abstract ---	1-6,11
Y	US,A,5 166 656 (BADIHI AVNER ET AL) 24 November 1992 cited in the application see the whole document ---	7-11
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 015 (E-1305), 12 January 1993 & JP,A,04 245129 (HITACHI CHEM CO LTD), 1 September 1992, see abstract ---	7-11
Y	GB,A,1 604 820 (LAUR KNUDSON NORDISK ELEKTRICI) 16 December 1981 see the whole document ---	7-11
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 015 (E-1305), 12 January 1993 & JP,A,04 245132 (HITACHI CHEM CO LTD), 1 September 1992, see abstract ---	7-11
Y	WO,A,91 14279 (MORRILL GLASSTEK INC) 19 September 1991 see figures 19-26 see page 22, paragraph 2 - page 25, paragraph 2 ---	7-11
Y	PATENT ABSTRACTS OF JAPAN vol. 016, no. 204 (E-1202), 15 May 1992 & JP,A,04 033230 (MITSUBISHI MATERIALS CORP;OTHERS: 01), 4 February 1992, see abstract ---	7-11
Y	GB,A,2 089 148 (WICKMANN WERKE GMBH) 16 June 1982 see the whole document ---	12-23
Y	PATENT ABSTRACTS OF JAPAN vol. 017, no. 019 (E-1306), 13 January 1993 & JP,A,04 248221 (HITACHI CHEM CO LTD), 3 September 1992, see abstract ---	12-23
1 A	DE,A,35 30 354 (OPEL ADAM AG) 5 March 1987 see column 2, line 11 - line 15 ---	
-/--		

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 96/09147

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 164 725 (WIEBE GERALD L) 14 August 1979 see column 10, line 14 - line 29 ---	
P,X	WO,A,95 33276 (LITTELFUSE INC) 7 December 1995 cited in the application see the whole document -----	1-23

## INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/US 96/09147

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0270954	15-06-88	JP-B- 8031303	27-03-96
		JP-A- 63141233	13-06-88
		DE-A- 3785835	17-06-93
EP-A-0581428	02-02-94	JP-A- 6036672	10-02-94
		US-A- 5309625	10-05-94
US-A-5166656	24-11-92	AU-A- 3787293	13-09-93
		EP-A- 0628211	14-12-94
		JP-T- 7504296	11-05-95
		US-A- 5296833	22-03-94
		WO-A- 9317442	02-09-93
		US-A- 5228188	20-07-93
GB-A-1604820	16-12-81	NONE	
WO-A-9114279	19-09-91	US-A- 5097245	17-03-92
		US-A- 5131137	21-07-92
		US-A- 5027101	25-06-91
		AT-T- 113755	15-11-94
		AU-A- 7556491	10-10-91
		CA-A- 2078122	14-09-91
		DE-D- 69104977	08-12-94
		DE-T- 69104977	04-05-95
		EP-A- 0513246	19-11-92
		US-A- 5155462	13-10-92
		US-A- 5224261	06-07-93
GB-A-2089148	16-06-82	DE-A- 3044711	01-07-82
		FR-A- 2494900	28-05-82
		JP-A- 57113535	15-07-82
DE-A-3530354	05-03-87	US-A- 4706059	10-11-87
US-A-4164725	14-08-79	US-A- 4203200	20-05-80
WO-A-9533276	07-12-95	US-A- 5552757	03-09-96
		AU-A- 2602495	21-12-95